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A KEY TO NORTH AMERICAN SPECIES OF *TRIOXYS* HALIDAY (HYMENOPTERA: BRACONIDAE: APHIDIINAE), WITH A SUMMARY OF THE GEOGRAPHIC DISTRIBUTION, HOSTS, AND SPECIES DIAGNOSTIC FEATURES

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Abstract.—A key to North American species of *Trioxys* (Hymenoptera: Braconidae: Aphidiinae) is provided along with summary tables on geographic origin, distribution, hosts, and diagnostic features. Accompanying the key are illustrations of the anterior portion of the forewing (stigma, R1 and Rs veins), propodeum, petiole, and genitalia, including the seventh metasomal sternite prongs and ovipositor sheaths.

Key Words: Aphidiinae, aphid, key, parasitoid, *Acanthocaudus*, *Betuloxys*, *Binodoxys*, *Trioxys*

Trioxys Haliday 1833, and other genera in Aphidiinae (Hymenoptera: Braconidae), include larval endoparasitoids of aphid nymphs and adults. There are over 70 species in *Trioxys* worldwide (Smith 1944; Mackauer 1959, 1960, 1961, 1965, 1967; Takada 1966, 1979; Starý and Schlinger 1967; Starý 1969, 1976, 1978, 1979; Carver and Starý 1974; Starý and Remaudière 1977, 1982; Starý and Bhagat 1978; Starý and Juchnevič 1978; Marsh 1979; Starý and Marsh 1982; Gärdenfors 1990; Mescheloff and Rosen 1993; Starý and Zuparko 1995; Pike et al. 2000; Chen and Shi 2001; Tomanović and Kavallieratos 2002; Davidian 2005; Fulbright and Pike 2007).

Few keys exist for distinguishing North America aphidiines, and none are comprehensive for *Trioxys*. An early key by Gahan (1911) recognized four species of *Trioxys*, Smith (1944) recognized 11 species, and since then *Trioxys* has been broken into several distinct genera or subgenera (Mackauer 1960, Mackauer 1965, Starý and Schlinger 1967, Starý 1981, Starý and Remaudière 1982, van Achterberg 1997, Chen and Shi 2001, Davidian 2005). Keys have been developed for individual aphidiine genera in North America, including Johnson's (1987) key to *Praon* Haliday, and Pike et al.'s (1999) key to *Ephedrus* Haliday. Keys specific to certain plant-aphid associations also exist, such as a key to the small grain aphid parasitoids (Pike et al. 1997a). An updated review of aphid parasitoids of the Pacific Northwest USA (Pike et al. 2000) brought together extensive information on tritrophic associations and descriptions of new species, including species of *Trioxys*, but no keys were presented.

Trioxys can be recognized by the female's distinctive paired prongs, which are extensions of the seventh metasomal sternite, and the petiole bearing spiracular tubercles only. Four other aphidiine genera in North America, *Acanthocaudus* Smith, *Betuloxys* Mackauer, *Binodoxys* Mackauer, and *Cristicaudus* Starý and Remaudière, also possess metasomal sternite prongs. *Acanthocaudus*, *Binodoxys*, and *Cristicaudus* differ in having secondary, as well as spiracular tubercles, on the petiole. *Betuloxys* bears only spiracular tubercles, but the apical portions of the prongs are differentiated, dilated, and bear several lanceolate, perpendicular setae on the dorsal surface. *Acanthocaudus* further differs from *Trioxys*, *Betuloxys*, *Binodoxys*, and *Cristicaudus* in having a secondary projection on its prongs (Starý 1981).

Species within *Trioxys* can be distinguished by one or more of the following features: propodeal areola presence or absence, antennal flagellomere number, metasomal sternite prong shape and length, prong dorsal and ventral setae number, prong apical bristle type and number, ovipositor sheath shape, and forewing stigma and R1(=metacarpus) length. Information on host specificity is also helpful for species differentiation. The North American and world distributions, as well as host aphid associations of each species, as presently recognized, are provided in the paper.

Materials and Methods

Material examined.—*Trioxys* species examined were from authors' field collections and museum loans. Numbers of specimens examined and location are as follows : *T. ameraceris* – type USNM (National Museum of Natural History, Washington), 2 paratypes Czech (Czech Academy of Sciences, P. Starý collection); *T. artemisiarum* – type USNM, 24 paratypes [19 WSU (Washington State University-Prosser), 3 Czech and 2 USNM]; *T. auctus* – 2 UCB (University of California-Berkeley), 1 Czech; *T. betulae* – 5 Czech; *T. bonnevillensis* – 156 WSU, 20 Czech; *T. californicus* – type UCB; *T. cirsii* – 1 WSU, 1 Czech; *T. complanatus* – 21 WSU, 11 Czech; *T. curvicaudus* – 20 UCB, 5 WSU, 11 Czech; *T. exareolatus* – type USNM; *T. gahani* – type USNM, 2 WSU; *T. ibis* – 2 Czech; *T. infrequens* – type USNM; *T. latgei* – 6 Czech; *T. mexicanus* – 2 Czech; *T. monelliopsis* – 3 Czech; *T. pallidus* – 261 WSU, 35 Czech; *T. rosae* – type USNM, 6 paratypes [4 WSU, 6 Czech, 2 USNM]; *T. setaceus* – type USNM, paratypes (3 WSU, 2 Czech); *T. sunnysidensis* – type USNM, 40 paratypes [WSU 26, 8 USNM, 6 Czech]; *T. tenuicaudus* – 2 WSU, 1 Czech). Authors' collections were preserved in 70–95% ETOH, some as whole mounts on pointed or rectangular paper tabs, and some as whole and/or dissected mounts on glass slides.

Slide mounted whole specimen preparation.—Parasitoids were cleared and mounted using techniques by P. Starý, and modified by G. Graf of Washington State University as follows: (1) parasitoid immersed in 95% ETOH; (2) specimen transferred to new test tube of water and inverted several times; (3) water decanted and specimen placed in test tube of 10% KOH; (4) test tube placed in heating block for approximately 2 minutes at 98°C (heating time varied depending on sclerotization and state of specimen; dry materials required more time); (5) specimen removed from KOH, placed in test tube of water and washed and inverted several times to rinse off KOH; (6) specimen placed in 3 drops of mounting medium (200 g gum arabic, 550 g chloral hydrate, 60 ml glycerin, and 400 ml distilled water mixed and filtered through glass wool) and positioned; (7) coverslip placed over specimen; (8) code number written on slide and slide allowed to dry horizontally for 2–3 weeks on slide warmer at 50°C; (9) mount sealed around

coverslip with glyptal, an alkyd-based sealant, to prevent dehydration and crystallization (Pike et al. 2003); and (10) slide fully labeled.

Parasitoid dissection.—Specimens were sometimes dissected for better feature viewing after placement in mounting medium as follows: (1) head cut from body with antennae attached or separated; (2) mesonotum separated from body with wings attached or separated; (3) propodeum separated from body, petiole sometimes left connected to propodeum in smaller specimens; (4) hind legs separated from body; (5) metasoma cut and positioned for (a) dorsal view of petiole and (b) posterior view of metasoma, including lateral view of genitalia; and (6) genitalia removed from metasoma if not protruding or visible.

Slide mounted specimen measurements.—Whole and dissected mounts were reticle measured using a compound microscope at magnifications of 50–400×.

Dry mounted specimens.—Whole mounts were placed on pin-pointed or rectangular paper tabs.

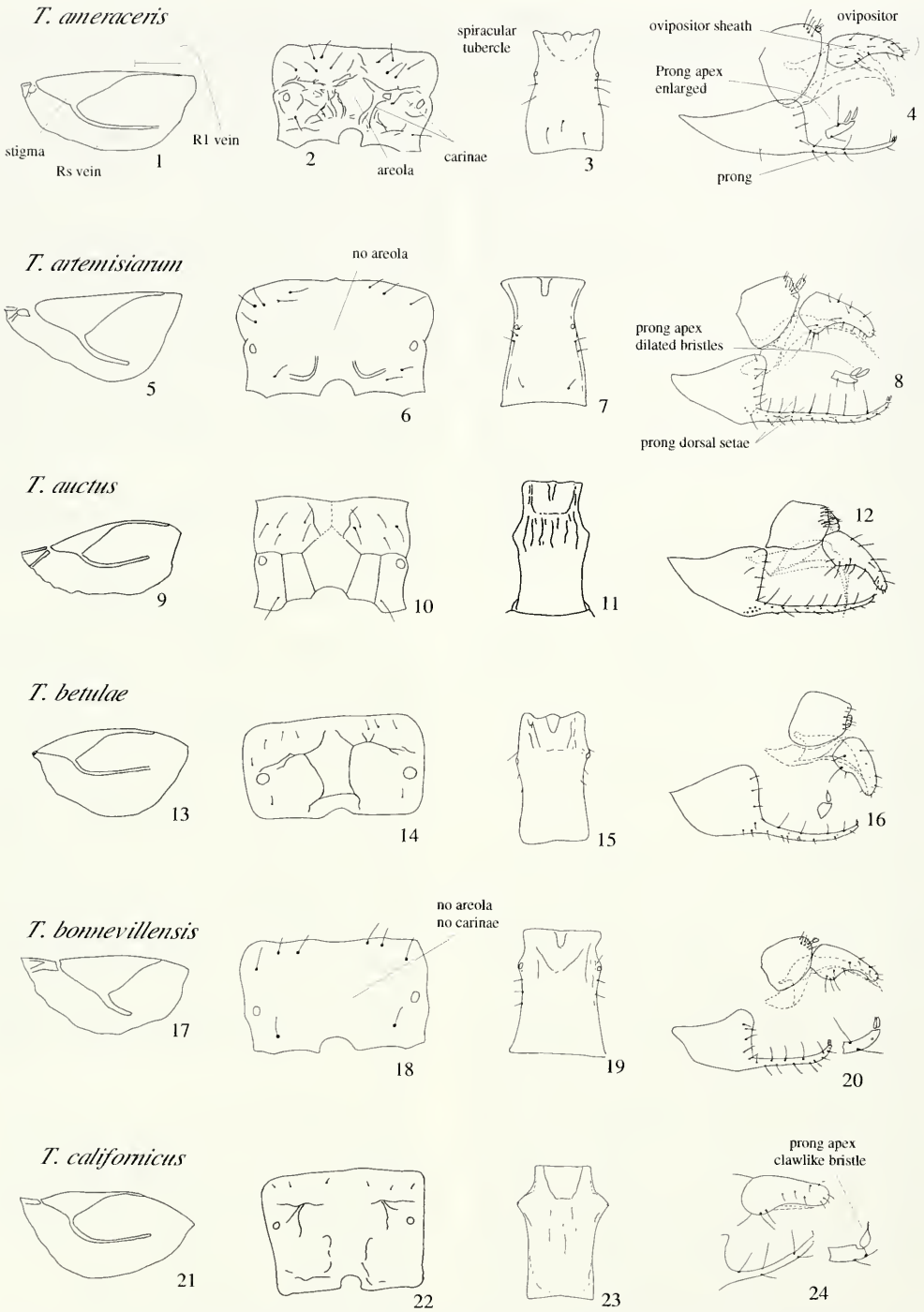
Illustrations.—Line drawings of many specimens were based on features captured with a Nikon Coolpix 990™ digital camera through an Olympus SZX12™ dissecting microscope or with a DEC13M™ digital eyepiece camera through a Zeiss Axiolab™ compound microscope. Illustrations of the wing, propodeum, petiole, genitalia and associated structures were provided for each species. For some rare species, illustrations were drawn from the type, i.e., *T. californicus* from the University of California Essig Museum of Entomology, and *T. exareolatus*, *T. gahani*, and *T. infrequens* from the National Museum of Natural History, Washington, DC. Other species were drawn from the type, paratype or other material, or redrawn after previously published drawings. Figs. 1–4, 7, 13, 17–23, 25–35, 37–52, 61–66b, 67, 77–84 were authors' original drawings; Fig. 50 was authors' conceptual illustration of the propodeum based on the original description (Smith 1944); Figs. 5, 6, and 8 were redrawn after Pike et al. 1997b; Fig. 9 after Mackauer 1959; Fig. 10 after Takada 1966; Figs. 11–12, 36 after Starý 1976; Fig. 14 after Tomanović and Kavallieratos 2002; Figs. 15–16 after Starý 1979; Fig. 24 after Starý and Zuparko 1995; Figs. 53–56 after Starý and Remaudière 1977; Figs. 57–60 after Starý and Remaudière 1982; Figs. 66c, 68 after Starý 1978; Figs. 69–72 after Pike et al. 1996; and Figs. 73–76 after Pike et al. 2000.

Terminology.—Descriptive morphology was after Sharkey and Wharton (1997).

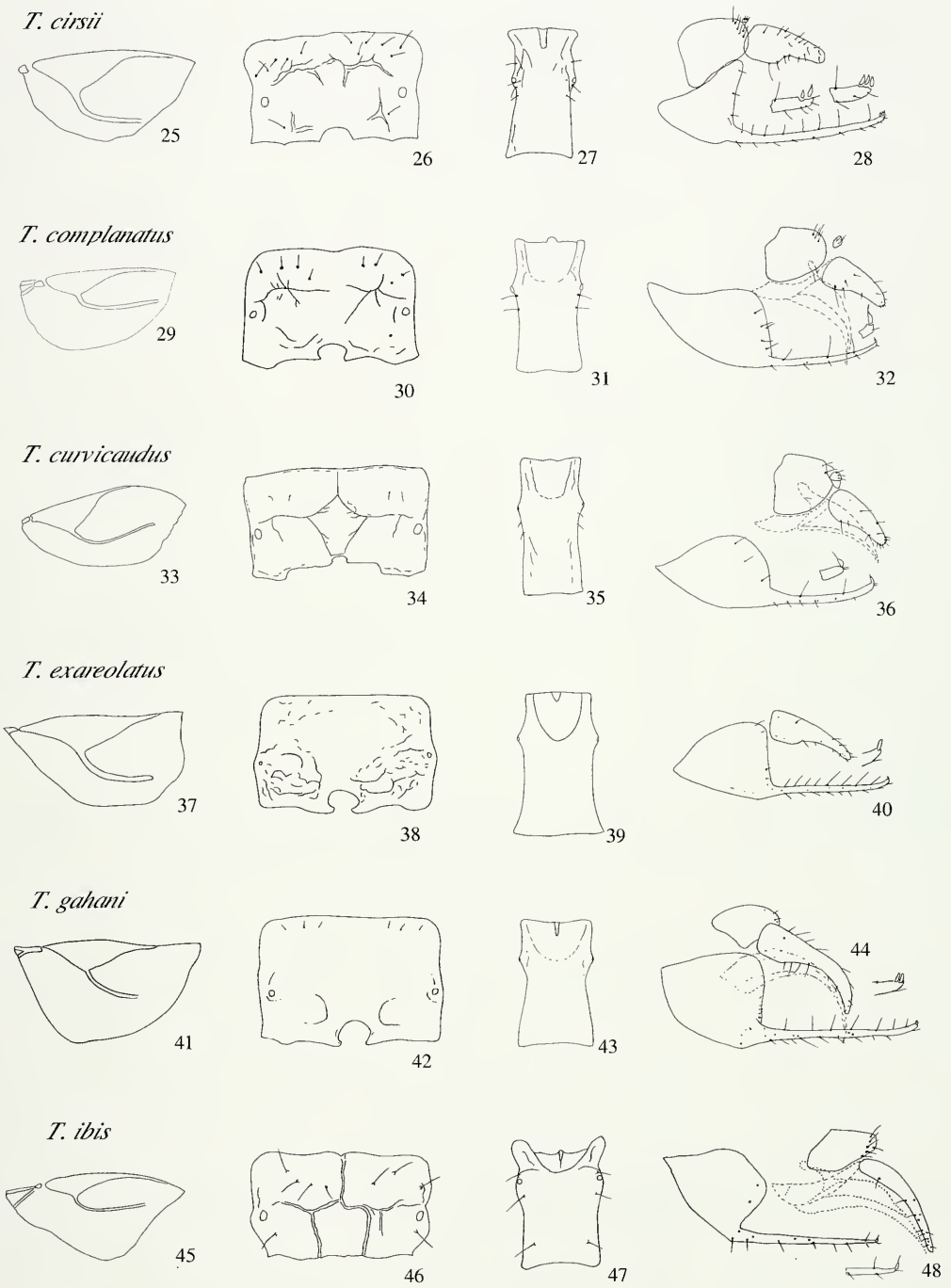
Results and Discussion

A listing of aphidiine parasitoids of North America can be found in Marsh (1979). Research within the past decade (Pike et al. 1996, 1997a, 2000) has supplemented the listing of taxa and aphid host range information. Table 1 summarizes the full listing of North American species of *Trioxys*. Host range, faunal composition, and ecology of *Trioxys* parasitoids for much of North America have not been explored thoroughly. As indicated in the introduction, there is a lack of updated keys for many genera of Aphidiinae, including *Trioxys*. Table 2 outlines distinguishing characters used in the key.

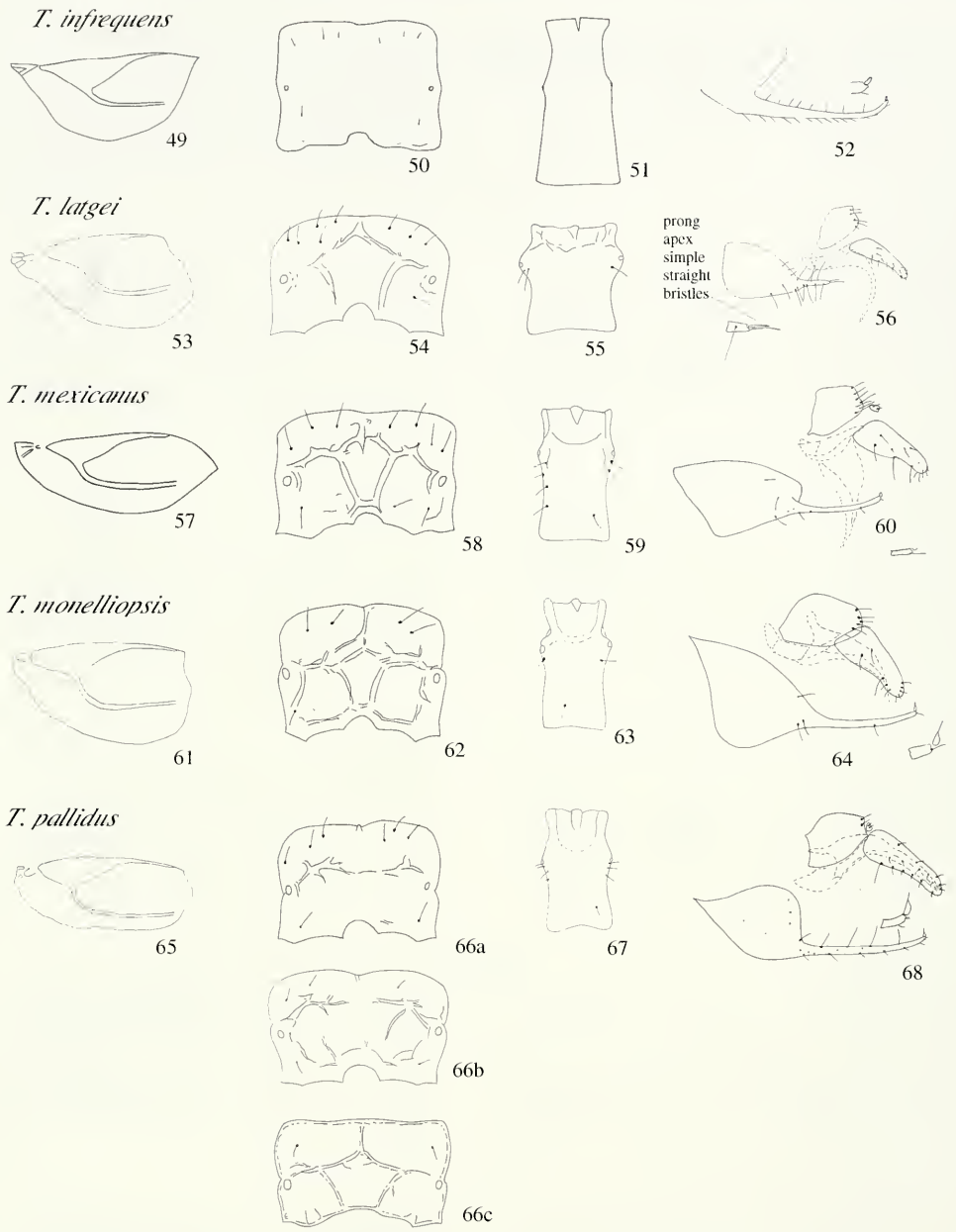
The North American *Trioxys* fauna is currently comprised of 22 species, 15 native and 7 introduced (Table 1). Members of the genus are associated with assorted groups of aphids in arboricolous, grassy riparian, sagebrush, and selected agroecosystem habitats. Eleven species of *Trioxys* utilize aphids in Myzocallidinae and Drepanosiphinae, most of which are arboricolous (i.e., aphids on alder, birch, crepe myrtle, elm, hazel, linden, maple, oak, pecan,



Figs. 1–24. *Trioxys* morphological features [columns 1, 2, 3, and 4 (left to right) = wings (part only), propodea, petioles, genitalia (includes last metasomal sternite prong and ovipositor sheath), respectively]. 1–4, *T. ameraceris*. 5–8, *T. artemisiarum*. 9–12, *T. auctus*. 13–16, *T. betulae*. 17–20, *T. bonnevillensis*. 21–24, *T. californicus*.

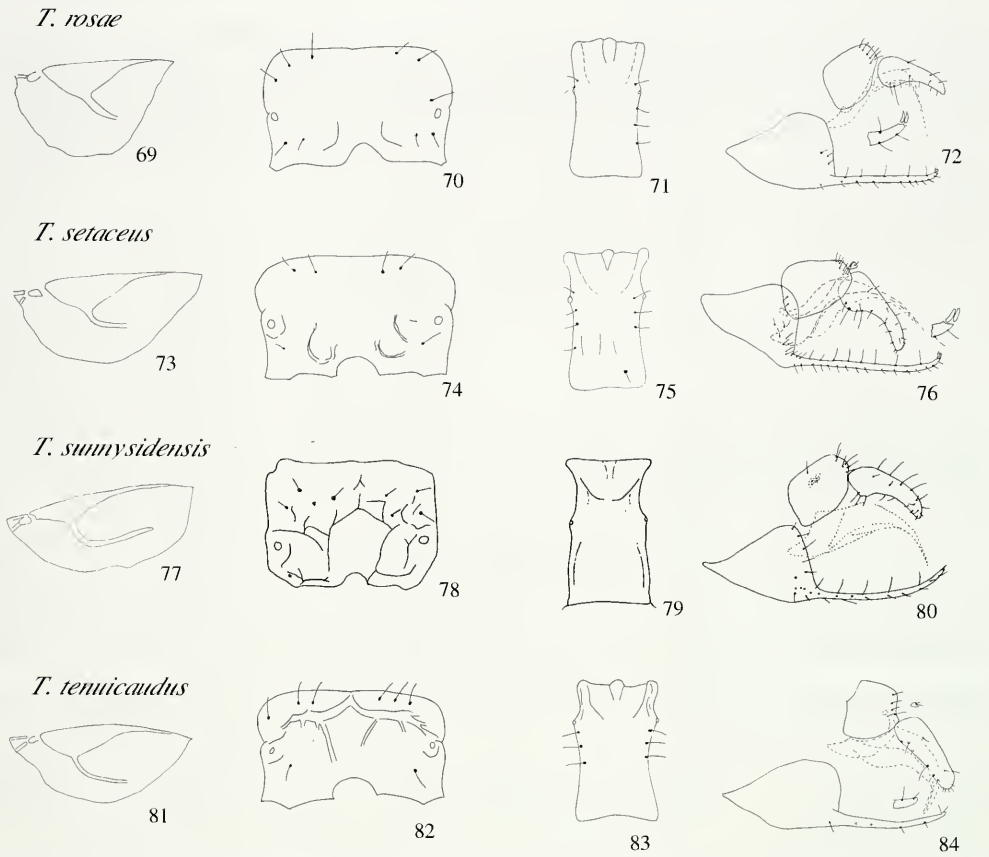


Figs. 25–48. *Trioxys* morphological features [columns 1, 2, 3, and 4 (left to right) = wings (part only), propodea, petioles, genitalia (includes last metasomal sternite prong and ovipositor sheath), respectively. 25–28, *T. cirsii*. 29–32, *T. complanatus*. 33–36, *T. curvicaudus*. 37–40, *T. exareolatus*. 41–44, *T. gahani*. 45–48, *T. ibis*.



Figs. 49–68. *Trioxys* morphological features [columns 1, 2, 3, and 4 (left to right) = wings (part only), propodea, petioles, genitalia (includes last metasomal sternite prong and ovipositor sheath), respectively. 49–52, *T. infrequens*. 53–56, *T. latgei*. 57–60, *T. mexicanus*. 61–64, *T. monelliopsis*. 65–68, *T. pallidus*.

and walnut). *Trioxys complanatus* Quilis uses a myzocallidine aphid on alfalfa, viz. the spotted alfalfa aphid, *Therioaphis trifolii* (Monell) (Table 1). Nine species of *Trioxys* attack solely aphids in Aphidiinae as follows: *T. auctus* (Haliday) on water lily aphid, *Rhopalosiphum nymphaeae* (L.) and bird cherry-oat aphid, *R. padi* (L.); *T. sunnysidensis* Fulbright and Pike on bird cherry-oat aphid; *T. artemisiarum* Pike and Starý and *T. bonnevillensis* Smith on sage aphids, *T. exar-*



Figs. 69–84. *Trioxys* morphological features [columns 1, 2, 3, and 4 (left to right) = wings (part only), propodea, petioles, genitalia (includes last metasomal sternite prong and ovipositor sheath), respectively. 69–72, *T. rosae*. 73–76, *T. setaceus*. 77–80, *T. sunnysidensis*. 81–84, *T. tenuicaudus*.

eolatus Viereck and *T. rosae* Pike and Starý on rose aphids; *T. gahani* Smith on blueberry aphid, *Ericaphis scammelli* (Mason) and *Chaetosiphon*; *T. latgei* Starý and Remaudière on juniper aphid, *Sanbornia juniperi* Pergande; and *T. setaceus* Pike and Starý on serviceberry aphid, *Acyrthosiphon macrosiphum* (Wilson) (Table 1). For two species of *Trioxys*, *T. infrequens* Smith and *T. ovalis* (Provancher), the hosts are unknown. Of the *Trioxys* species accidentally or purposely introduced into North America [*T. auctus* (Haliday), *T. betulae* Marshall, *T. cirsii* (Curtis), *T. complanatus* Quilis, *T. ibis* Mackauer, *T. pallidus* (Haliday), and *T. tenuicaudus* Starý], some have become adapted or partially adapted to native and/or long established introduced aphids.

Parasitoid determinations should be based on multiple factors whenever possible. Parasitoids which have been identified through the key should be checked against primary distinguishing features (Table 2), compared to the illustrations, and checked against the host aphid and distributional records where available.

Success in identifying parasitoids is facilitated when quality and quantity material are available. Freshly reared, cleared and mounted specimens are best. One of the challenges in making determinations with confidence is being able to see the key features. With point-

Table 1. *Trioxys* of North America: origin, hosts, North American distribution.

Species	Origin	Host Aphids Subfamily (Genus)	Reported Distribution
ameraceris Smith 1944	Nearctic	Drepanosiphinae (*Drepanaphis*)	E. Can., E. USA (Smith 1944, Marsh 1979)
artemisiarum Pike and Starý 1997	Nearctic	Aphidinae [*Aphis* (*Zyxaphis*), *Microsiphoniella*]	WA (Pike and Starý 1997b)
auctus (Haliday 1833)	Palearctic	Aphidinae (*Rhopalosiphum*)	E. Can. (QC)
betulae Marshall 1896	Palearctic	Myzocallidinae (*Calaphis*, *Clethrobius*, *Symydobius*)	E. Can. (NB, ON, QC.), NH (Marsh 1979)
bonnevillensis Smith 1944	Nearctic	Aphidinae (sage aphids[1])	ID, WA, UT, Mexico (Smith 1944, Starý and Remaudière 1982, Pike et al. 2000)
californicus Starý and Zuparko 1995	Nearctic	Myzocallidinae (*Eucallipterus*)	CA (Starý and Zuparko 1995)
cirsii (Curtis 1831)	European	Drepanosiphinae (*Drepanosiphum*)	WA (Pike et al. 2000)
complanatus Quilis 1931	Eurasian	Myzocallidinae (*Therioaphis*)	Can., USA (Marsh 1979, Pike et al. 2000)
curvicaudus Mackauer 1967	Nearctic	Myzocallidinae (*Eucallipterus*, *Tuberculatus*)	CA (Mackauer 1967, Starý 1978)
exareolatus Viereck 1916	Nearctic	Aphidinae (*Macrosiphum*)	CT (Viereck 1916, Marsh 1979)
gahani Smith 1944	Nearctic	Aphidinae (*Ericaphis*, *Chaetosiphon*)	NJ, WA (Smith 1944, Marsh 1979)
ibis Mackauer 1961	European	Myzocallidinae (*Betulaphis*)	E. Can. (NB) (Mackauer 1961, Marsh 1979)
infrequens Smith 1944	Nearctic	Unknown	W. Can., CO (Marsh 1979)
latgei Starý and Remaudière 1977	Nearctic	Aphidinae (*Sanbornia*)	ME (Starý and Remaudière 1977)
mexicanus Starý and Remaudière 1982	Nearctic	Myzocallidinae (*Myzocallis*)	Mexico (Starý and Remaudière 1982)
monelliopsis Starý and Marsh 1982	Nearctic	Myzocallidinae (*Monelliopsis*)	GA (Starý and Marsh 1982)
ovalis (Provancher 1886)	Nearctic	Unknown[2]	E. Can. (Smith 1939, 1944, Marsh 1979)
pallidus (Haliday 1833)	Palearctic	Myzocallidinae (tree aphids[3])	W. USA (Marsh 1979, Pike et al. 2000)
rosae Pike and Starý 1996	Nearctic	Aphidinae (*Macrosiphum*)	WA (Pike et al. 1996, 2000)
setaceus Pike and Starý 2000	Nearctic	Aphidinae (*Acyrthosiphon*)	MT, WA (Pike et al. 2000)
sunnysidensis Fulbright and Pike 2007	Nearctic	Aphidinae (*Rhopalosiphum*)	WA (Fulbright and Pike 2007)
tenuicaudus Starý 1978	Palearctic	Myzocallidinae (*Eucallipterus*, *Myzocallis*, *Tinocallis*, *Tuberculatus*)	WA (Starý 1978, Pike et al. 2000)

[1] *Aphis* (*Zyxaphis*), *Artemisaphis*, *Epameibaphis*, *Flabellomicrosiphum*, *Microsiphoniella*, *Obtusicauda*, *Pleotrichophorus*, *Pseudoepameibaphis*.

[2] Reared from an aphid on *Helianthus* sp. (Smith 1939).

[3] *Chromaphis*, *Eucallipterus*, *Hoplocallis*, *Monelliopsis*, *Myzocallis*, *Panaphis*, *Tinocallis*, *Tuberculatus*.

mounted specimens on pins, it is not always possible to see or see clearly all of the distinguishing characters used in the key. Clearing and slide mounting representative specimens is recommended, if not essential. Slide mounts, when properly sealed and labeled, become permanent holdings and are easily viewable.

Key to Female *Trioxys* of North America

[*Trioxys ovalis* (Provancher) de-

Table 2. *Trioxys* of North America: Antennal segment no., prong dorsal setae no., prong apical bristle type and no., and propodeal sculpture.

Species	Antennal Segment No.	Dorsal Setae No.	Apical Bristle Type	Apical Bristle No.	Propodeal Sculpture
ameraceris	11, 12 (rarely)	1–3	dilated	2	areola
artemisiarum	12	7	dilated	2	largely smooth, divergent posterior carinae
auctus	12	4–6	simple, straight	2	areola
betulae	11	2–6	claw	1	areola
bonnevillensis	11	4–5	dilated	2	smooth
californicus	13	3	clawlike	1	some carinae
cirsii	11	6–8	dilated	2 or 3	areola, may be incomplete
complanatus	11	2–4	clawlike	1	some carinae
curvicaudus	11	2–5	clawlike	1	areola
exareolatus	11?	8	dilated	1	some carinae
gahani	11	7	dilated	2	largely smooth, divergent posterior carinae
ibis	12	1	clawlike	1	areola
infrequens	11	8	dilated	1	smooth
latgei	11	3–4	simple, straight	2	areola
mexicanus	11	0	dilated	1	areola
monelliopsis	11	0	clawlike	1	areola
pallidus	11	3–4	clawlike	1	areola (part) or irregular lateral carinae
rosae	11	4–5	dilated	2	largely smooth, divergent posterior carinae
setaceus	11	6–8	dilated	2	some carinae
sunnysidensis	11 (rarely), 12	4–5	simple, straight	2	areola
tenuicaudus	11	1	simple, straight	1	areola

scribed in 1886 from Ontario, Canada not included in key; type lost, description inadequate, placement uncertain.]

1. Propodeum with an areola (Fig. 2), may be open (Figs. 26, 82) 2
– Propodeum without an areola, smooth (Fig. 18) or with some carinae (Figs. 22, 42) 13

2(1). Prong with clawlike (Figs. 24, 64) or dilated apical bristle(s) (Figs. 4, 8) 3
– Prong with straight simple bristle(s) (Fig. 56) 10

3(2). Prong with single clawlike apical bristle (Fig. 64) 4
– Prong with dilated apical bristle(s) (Figs. 4, 60) 8

4(3). Prong dorsal surface with setae (Fig. 8) 5
– Prong dorsal surface without setae (Fig. 64); (host, *Monelliopsis nigropunctata* on pecan; Georgia) (Figs. 61–64) . . . . . *monelliopsis* Starý and Marsh

5(4). Ovipositor sheath long and narrow (Fig. 48); stigma length 3× width; antenna 12-segmented; host, *Betulaphis quadrituberculata* on birch; Europe, New Brunswick) (Figs. 45–48) . . . . . *ibis* Mackauer
– Not with combination of features above . . 6

6(5). Prongs fused from base for more than half their length (hosts, *Calaphis*, *Cletlirobius*, *Symydobius* on alder or birch; Asia, eastern Canada, Europe, Russia, (Figs. 13–16) . . . . . *betulae* Marshall
– Prongs distinctly separated 7

7(6). Prong dorsal surface with 2 setae (Fig. 36) ; prongs arcuate at apex (hosts, *Eucallipterus tiliae* on linden and *Tuberculatus* on oak; California, Europe, and Russia) (Figs. 33–36) *curvicaudus* Mackauer
– Prong dorsal surface with 3–4 setae (Fig. 68); prongs relatively straight (hosts, various tree aphids, *Chromaphis*, *Eucallipterus*, *Hoplocallis*, *Monellia*, *Monelliopsis*, *Myzocallis*, *Tuberculatus*, *Tinocallis*, *Panaphis*; Asia, Australia, Europe, Russia, Tasmania [specimens with propodeal areola not observed in North America]) (Figs. 65–68) . . . *pallidus* (Haliday) (in part)

8(3). Prong dorsal surface without setae (Fig. 60); 1 dilated apical bristle (host,

Myzocallis on oak; Mexico) (Figs. 57–60) . . . . . *mexicanus* Starý and Remaudière

– Prong dorsal surface with setae; 1–3 dilated apical bristles (Figs. 4, 28) 9

9(8). Prong dorsal surface with 2–3 setae (Fig. 4) (host, *Drepanaphis* on maple; eastern Canada, Florida, Missouri, Ohio, Tennessee) (Figs. 1–4) . . . *aneraceris* Smith

– Prong dorsal surface with 6–8 setae (Fig. 28) (host, *Drepanosiphum* on maple; known distribution, Asia, Australia, Europe, Washington) (Figs. 25–28) *cirsii* (Curtis)

10(2). Prong short and straight, with two long apical bristles (Fig. 56); petiole short, only slightly longer than wide (Fig. 55) (host, *Sanbornia juniperi* on juniper; Maine) (Figs. 53–56) . . . *latgei* Starý and Remaudière

– Not with the combination of features above 11

11(10). Prong dorsal surface with one preapical seta (Fig. 84); ovipositor sheath very shallowly emarginate on ventral side (Fig. 84) (host, various tree aphids – *Eucallipterus*, *Myzocallis*, *Tinocallis*, *Tuberculatus*; Australia, Europe, Russia, and Washington) (Figs. 81–84) *tenuicaudus* Starý

– Prong dorsal surface with 4 or more setae (Fig. 80) 12

12(11). Petiole with numerous longitudinal striations in proximal half (Fig. 11) (host, *Rhopalosiphum*; Eurasia and Ontario [introduced]) (Figs. 9–12) . . . *auctus* (Haliday)

– Petiole without striations (Fig. 79) (host, *Rhopalosiphum* on wheat; Washington) (Figs. 77–80) . . . . . *sunnysidensis* Fulbright and Pike

13(1). Antenna 13-segmented (host, *Eucallipterus tiliae*; California; species rare, described from a single specimen) (Figs. 21–24) . . . . . *californicus* Starý and Zuparko

– Antenna 11–12 segmented 14

14(13). Petiole dilating from poorly prominent spiracular tubercles to apex (Fig. 7); antenna 12-segmented; (hosts, various sagebrush aphids – *Aphis* (*Zyxaphis*), *Microsiphoniella*; Washington) (Figs. 5–8) . . . . . *artemisiarum* Pike and Starý

– Petiole spiracles on prominently visible tubercles (Fig. 51) antenna usually 11-segmented; 15

15(14). Prong dorsal surface with 6–8 setae (Fig. 52) 16

– Prong dorsal surface with 2–5 setae (Fig. 20) 19

16(15). Petiole length/width at spiracles ≥ 2 (Figs. 51); propodeum smooth (host, unknown; Colorado, western Canada) (Figs. 49–52) . . . . . *infrequens* Smith

– Petiole length/width at spiracles 1.5–1.9 (Figs. 39, 43, 75); propodeum with some carinae (Figs. 38, 42, 74) 17

17(16). Prong ventral surface with > 12 setae (Fig. 76) (host, *Acyrthosiphon macrosiphum* on western serviceberry; Montana and Washington) (Figs. 73–76) . . . . . *setaceus* Pike and Starý

– Prong ventral surface with usually < 10 setae (Figs. 40, 44) (host,not *Acyrthosiphon macrosiphum*) 18

18(17). Prong dorsal surface bearing 4 distal setae approximately twice as long as 4 basal setae; tip of R1 vein yellowish or light ferruginous (Smith 1944); stigma length about 2× R1 vein; F1 and F2 antennal segments long, 0.19 and 0.16 mm, respectively (host, rose aphid; Connecticut, rare, described from a single specimen) (Figs. 37–40) . . . . . *exareolatus* Viereck

– Prong dorsal surface setae not as above; F1 and F2 antennal segments short, each 0.11–0.12 mm (hosts, *Ericaphis*, *Chaetosiphon*; New Jersey and Washington) (Figs. 41–44) . . . . . *gahani* Smith

19(15). Propodeum entirely smooth (Fig. 18), R1 vein short, < 0.25× stigma length (Fig. 17) (hosts, sage aphids – *Aphis* (*Zyxaphis*), *Artemisaphis*, *Epameibaphis*, *Flabellomicrosiphum*, *Microsiphoniella*, *Obtusicauda*, *Pleotrichophorus*, *Pseudoepameibaphis*; Idaho, Mexico, Utah, and Washington) (Figs. 17–20) . . . . . *bonnevillensis* Smith

– Propodeum with at least some carinae (Figs. 30), R1 vein length variable 20

20(19). Propodeum smooth except for divergent carinae in posterior declivity (Fig. 70); R1 vein 0.3× stigma length (Fig. 69); (host, *Macrosiphum rosae* on rose; Washington) (Figs. 69–72) . . . . . *rosae* Pike and Starý

– Propodeum with irregular lateral carinae (Figs. 30, 66a, 66b); R1 vein 0.4× stigma length or greater (Figs 29, 65) 21

21(20). [Species in couplet morphologically similar – check for a match with correct host] Ovipositor sheath ventral margin with 5–7 setae excluding apical setae (Fig. 68) (hosts, various tree aphids – *Chromaphis*, *Eucallipterus*, *Hoplocallis*, *Monellia*, *Monelliopsis*, *Myzocallis*, *Tuberculatus*, *Tinocallis*, *Panaphis*; California, Oregon, Washington (Figs. 65–68) . . . . *pallidus* (Haliday) (in part)

– Ovipositor sheath ventral margin with 3–4 setae excluding apical setae (Fig. 32) (hosts, *Therioaphis* – North America;, *Pterocallis* – Eurasia) (Figs. 29–32) . . *complanatus* Quilis

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Literature Cited

Carver, M. and P. Starý. 1974. A preliminary review of the Aphidiidae (Hymenoptera: Ichneumonoidea) of Australia and New Zealand. Journal of Australian Entomological Society 13: 235–240.

Chen, J. and Q. Shi. 2001. Systematic Studies on Aphidiidae of China (Hymenoptera: Aphidiidae). Fujian Science and Technology Press, Fuhzhou. 273 pp.

Curtis, J. 1831. British entomology; being illustrations and descriptions of the genera of insects found in Great Britain and Ireland. Printed by the author, London 8: 383.

Davidian, E. M. 2005. A review of species of the subgenus *Trioxys* s. str., genus *Trioxys* Hal. (Hymenoptera: Aphidiidae) of Russia and adjacent countries. Entomogitsheskoe Obozrenie 84: 579–609.

Fulbright, J. L. and K. S. Pike. 2007. A new species of *Trioxys* (Hymenoptera: Braconidae: Aphidiinae) parasitic on the bird cherry-oat aphid, *Rhopalosiphum padi* (L.) (Hemiptera: Aphididae) in the Pacific Northwest. Proceedings of the Entomological Society of Washington 109: 541–546.

Gahan, A. B. 1911. Aphidiinae of North America. Maryland Agricultural Experiment Station Research Bulletin 152: 147–200.

Gärdenfors, U. 1990. *Trioxys apterus* sp. n. from Ecuador, a new wingless species of Aphidiinae (Hymenoptera: Braconidae). Entomologica Scandinavica 21: 67–69.

Haliday, A. H. 1833. An essay on the classification of the parasitic Hymenoptera of Britain, which correspond with the Ichneumones minuti of Linnaeus. Entomological Magazine 1: 259–276.

Johnson, J. W. 1987. A revision of the species of *Praon* Haliday in North America north of Mexico (Hymenoptera: Aphidiidae). Canadian Entomologist 119: 999–1025.

Mackauer, M. 1959. Die mittel-, west- und nordeuropäischen Arten der Gattung *Trioxys* Haliday. Beiträge zur Entomologie 9: 144–179.

———. 1960. Zur systematic der Gattung *Trioxys* Haliday. Beiträge zur Entomologie 10: 137–160.

———. 1961. Neue europäische Blattlaus-Schlupfwespen (Hymenoptera: Aphidiidae). Bollettino del Laboratorio di entomologia agraria Filippo Silvestri Portrici 19: 270–290.

———. 1965. Notes on and additions to the *Trioxys* and *Binodoxys* species (Hymenoptera: Aphidiidae) of North America. Canadian Entomologist 97(3): 225–231.

———. 1967. A new genus and several new species of aphid parasites. Entomophaga 12(2): 139–147.

Marsh, P. M. 1979. Aphidiidae, pp. 295–313. *In* Krombein, K. V., P. D. Hurd, D. R. Smith, and D. B. Burks, eds. Catalog of Hymenoptera of America North of Mexico, Vol. 1 Symphyta and Apocrita (Parasitica). Smithsonian Institution Press, Washington D. C. 1198 pp.

Marshall, T. A. 1896. Braconides. *In* André, E. ed. Species des Hyménoptères d'Europe et d'Algérie. Bouffaut Frères, Paris, Gray, 5. 635 pp.

Mescheloff, E. and D. Rosen. 1993. Biosystematic studies on the Aphidiidae of Israel (Hymenoptera: Ichneumonoidea). Israel Journal of Entomology 25: 31–47.

Pike, K. S., L. L. Boydston, and D. W. Allison. 2003. Aphids of western North America north of Mexico with keys to subfamilies and genera for female alatae. Washington State University Cooperative Extension MISC0523, Pullman, Washington. 282 pp.

Pike, K. S., P. Starý, R. Miller, D. Allison, L. Boydston, G. Graf, and T. Miller. 1996. New species and host records of aphid parasitoids (Hymenoptera: Braconidae: Aphidiinae) from the Pacific Northwest, U.S.A. Proceedings of the Entomological Society of Washington 98: 570–591.

Pike, K. S., P. Starý, T. Miller, D. Allison, L. Boydston, G. Graf, and R. Gillespie. 1997a. Small-grain aphid parasitoids (Hymenoptera: Aphelinidae and Aphidiidae) of Washington: Distribution, relative abundance, seasonal occurrence, and key to known North American species. Environmental Entomology 26: 1299–1311.

Pike, K. S., P. Starý, G. Graf, D. Allison, L. Boydston, R. Miller, and T. Miller. 1997b. Parasitoids (Hymenoptera: Braconidae: Aphi-

diinae) of aphids on big sagebrush (*Artemisia tridentata*) and prairie sage (*Artemisia ludoviciana*) in Washington State. Proceedings of the Entomological Society of Washington 99: 143–155.

Pike, K. S., P. Starý, T. Miller, R. Miller, D. Allison, G. Graf, and L. Boydston. 1999. *Ephedrus clavicornis* sp. n. (Hymenoptera, Braconidae, Aphidiinae), an aphid parasitoid of the Pacific Northwest, and key to nearctic *Ephedrus*. Journal of the Kansas Entomological Society 72: 10–16.

Pike, K. S., P. Starý, T. Miller, G. Graf, D. Allison, L. Boydston, and R. Miller. 2000. Aphid parasitoids (Hymenoptera: Braconidae: Aphidiinae) of Northwest USA. Proceedings of the Entomological Society of Washington 102: 688–740.

Provancher, L. 1886. Additions et corrections à la Faune hyménoptèrologique de la Province de Québec. C. Darveau, Québec. 475 pp.

Quilis Pérez, M. 1931. Especies nuevas de Aphidiidae españoles (Hymenoptera: Braconidae). Eos, Madrid 7: 25–84.

Sharkey, M. J. and R. A. Wharton. 1997. Morphology and terminology, pp. 19–37. *In* Wharton, R. A., P. M. Marsh, and M. J. Sharkey, eds. Manual of the New World genera of the family Braconidae (Hymenoptera). Special Publication, No. 1, International Society of Hymenopterists, Washington, DC. 439 pp.

Smith, C. F. 1939. Hymenopterous parasites of aphids with special reference to the Aphidiinae. Ph.D. Dissertation, The Ohio State University, Columbus, Ohio. 133 pp.

———. 1944. The Aphidiinae of North America (Braconidae: Hymenoptera). Ohio State University Contributions in Zoology and Entomology No. 6, 164 pp.

Starý, P. 1969. Aphids and their parasites associated with oaks in Iraq. Proceedings of the Entomological Society of Washington 71(3): 279–297.

———. 1976. Aphid Parasites (Hymenoptera: Aphidiidae) of the Mediterranean Area. W. Junk, The Hague. 95 pp.

———. 1978. Parasitoid spectrum of the arboricolous callaphidid aphids in Europe (Hymenoptera, Aphidiidae; Homoptera, Aphidoidea, Callaphididae). Acta Entomologica Bohemoslovaca 75: 164–177.

———. 1979. Aphid Parasites (Hymenoptera: Aphidiidae) of the Central Asian Area. W. Junk, The Hague. 114 pp.

———. 1981. Biosystematical classification of *Trioxys* Haliday and related genera (Hymenoptera, Aphidiidae). Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri 38: 85–93.

Starý, P. and R. C. Bhagat. 1978. Records and descriptions of aphid parasitoids from Kashmir, India (Hymenoptera: Aphidiidae). Acta Entomologica Bohemoslovaca 75: 387–393.

Starý, P. and L. A. Juchnevič. 1978. Aphid parasites (Hymenoptera, Aphidiidae) from Kazakhstan, USSR. Bulletin Entomologique de Pologne 48: 523–532.

Starý, P. and P. M. Marsh. 1982. A new species of *Trioxys* (Hymenoptera: Aphidiidae) parasitic on a pecan aphid. Proceedings of the Entomological Society of Washington 84(4): 726–728.

Starý, P. and G. Remaudière. 1977. Some aphid parasitoids (Hymenoptera: Aphidiidae) from nearctic America. Annales de la Société Entomologique de France, N.S. 13: 669–674.

———. 1982. New genera, species and host records of aphid parasites (Hymenoptera: Aphidiidae) from Mexico. Annales de la Société Entomologique de France, N.S. 18: 107–127.

Starý, P. and E. I. Schlinger. 1967. A revision of the Far East Asian Aphidiidae (Hymenoptera). W. Junk, The Hague, Netherlands. 204 pp.

Starý, P. and R. L. Zuparko. 1995. A new species of *Trioxys* (Hymenoptera: Braconidae) from California. Pan-Pacific Entomologist 71: 173–175.

Takada, H. 1966. A preliminary revision of species of *Trioxys* Haliday occurring in Japan, with descriptions of eight new species. Insecta Matsumurana 29: 23–36.

———. 1979. Aphidiidae (Hymenoptera) from Mongolia. Folia Entomologica Hungarica 32: 189–202.

Tomanović, Ž. and N. G. Kavallieratos. 2002. *Trioxys* Haliday (Hym.: Braconidae: Aphidiinae) in Serbia and Montenegro. Acta Entomologica Serbica 7: 67–81.

van Achterberg, C. 1997. Subfamily Aphidiinae, pp. 119–131. *In* Wharton, R. A., P. M. Marsh, and M. J. Sharkey, eds. Manual of the New World Genera of the Family Braconidae (Hymenoptera). Special Publication, No. 1, International Society of Hymenopterists, Washington, DC. 439 pp.

Viereck, H. L. 1916. The Hymenoptera, or wasp-like insects of Connecticut, Part III. Connecticut State Geological and Natural History Survey Bulletin 22: 1–824.